G4numi beam Monte Carlo

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Before g4numi

- Numi MC baseline:
  - FLUKA simulation of the target
  - Output from fluka input to gnumi(Geant3)
  - Geant3 used to propagate particles through horns to their decay point
    - - gfluka (fluka 1993) simulation of interactions downstream of target

- Cross checks using other MCs (mars, gfluka) and parameterizations (BMPT (SPY), Malensek (Atherton))

New beam MC

- Wanted to upgrade:
  - move toward more modern models
  - looked for well documented and maintained MC
  - easy to maintain/upgrade the code

- Geant4 obvious candidate
  - C++ based
  - Well maintained, lot of users, active forums
  - But, prefered fluka to geant4 physics

MC interfaces

- Virtual MC (integrated into ROOT framework)
  - Interfaces with geant3, geant4, (fluka)

- Flugg
  - **flu**ka with **g**eant4 **g**eometry
  - Interface between geant4 and fluka

VMC

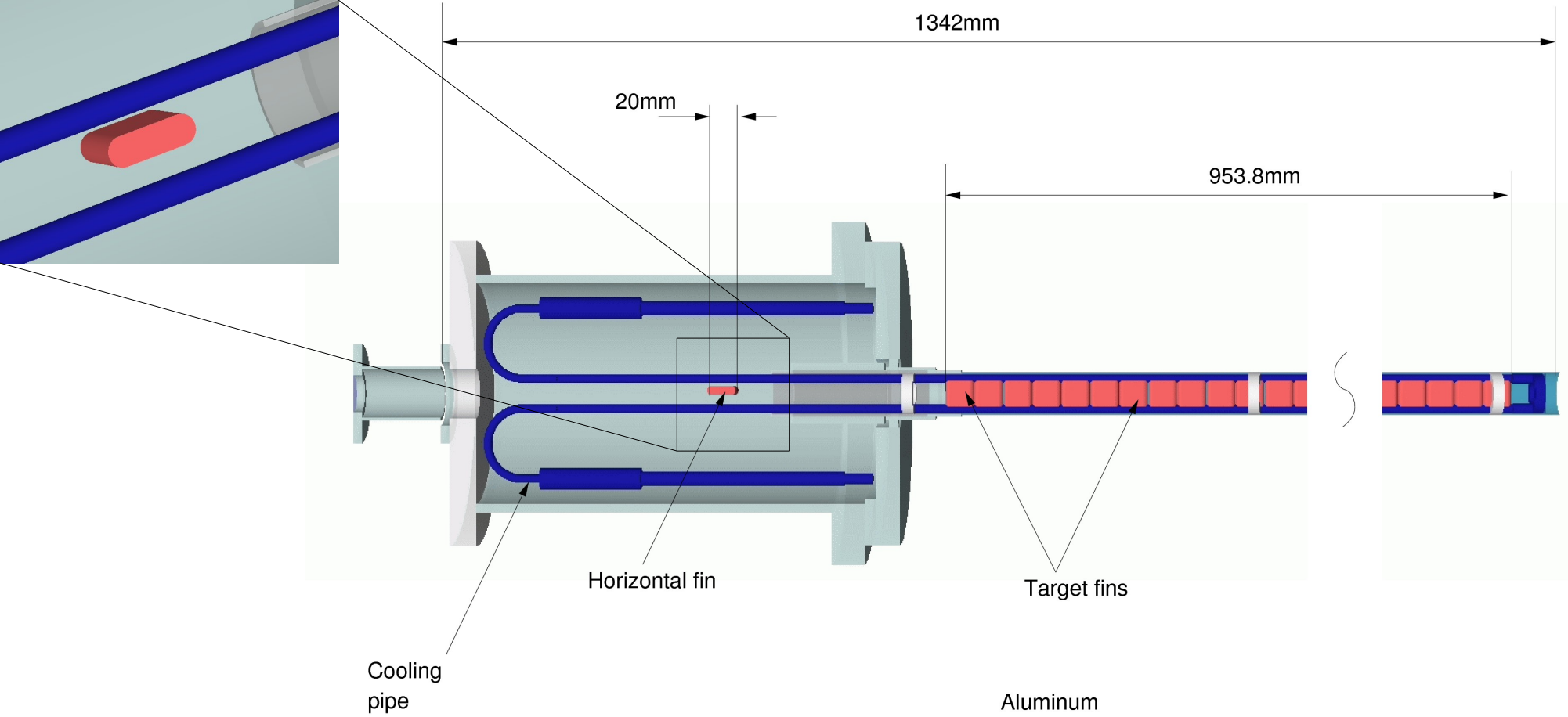
- Fluka interface wasn't available at the time we started developing new MC
- Eventually it did become available, however from mail sent recently to fluka users:

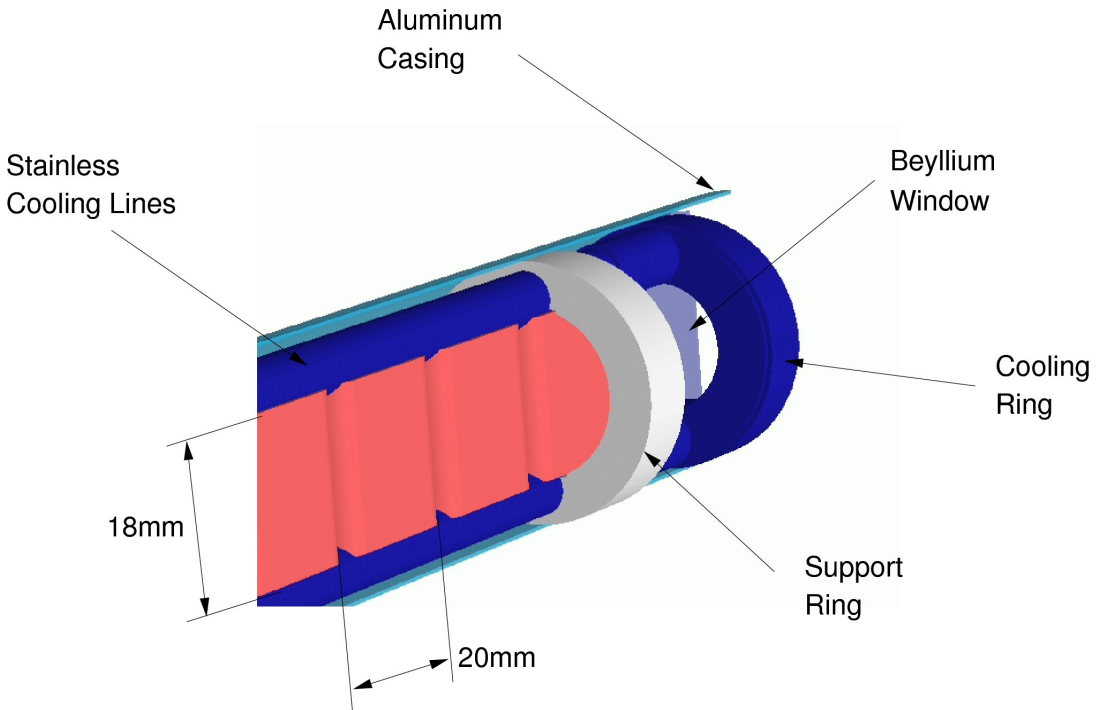
> Dear FLUKA users,
>
> we regretfully have to announce that the use of the FLUKA-VMC interface is
>
> no longer permitted or supported, with the only exception of the Alice collaboration. Whichever further use of that interface will be considered an infringement to the FLUKA license.
>
> ....

g4numi

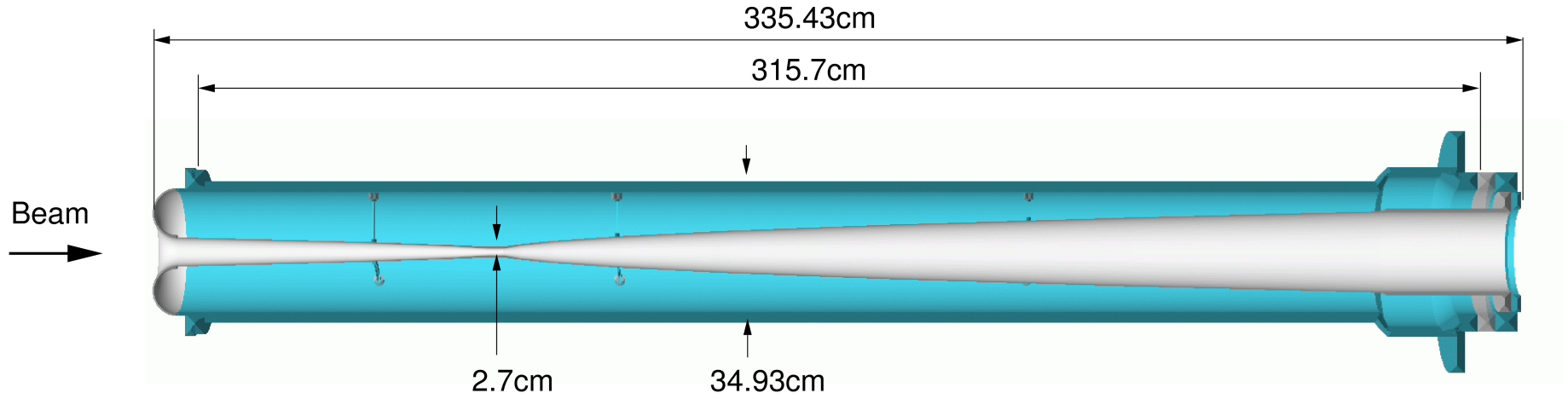
- Geant4 based
- Similar to gnumi
  - Same weighting technique
  - Almost identical output format (same variables)
    - g4numi → root ntuple
    - g4numi_flugg → ascii file
- Use geant4 classes to describe geometry
  - Considered using xml:
    - xml to g4 geometry wasn't perfect (not all of the shapes were supported)
- Can add flugg on top to interface with fluka

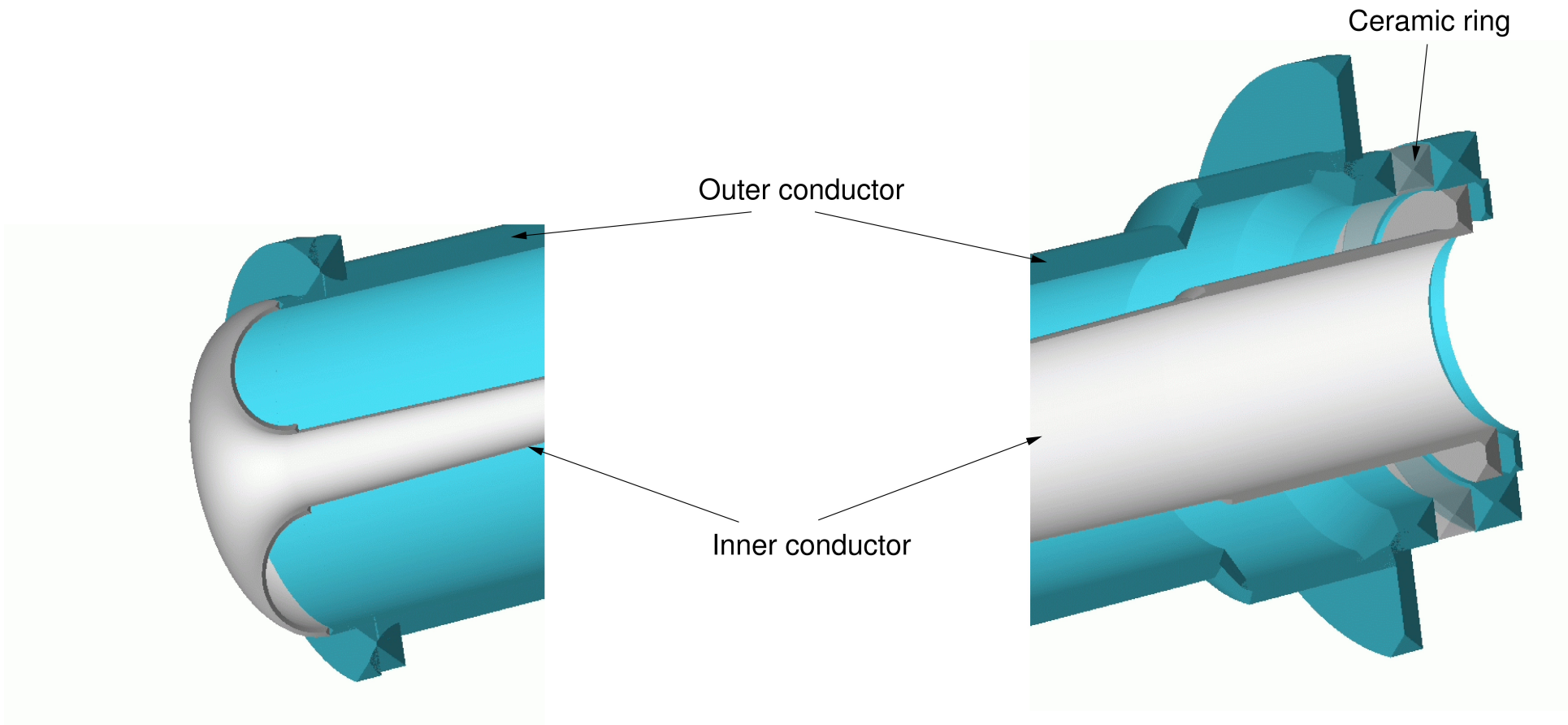
Geometry - target



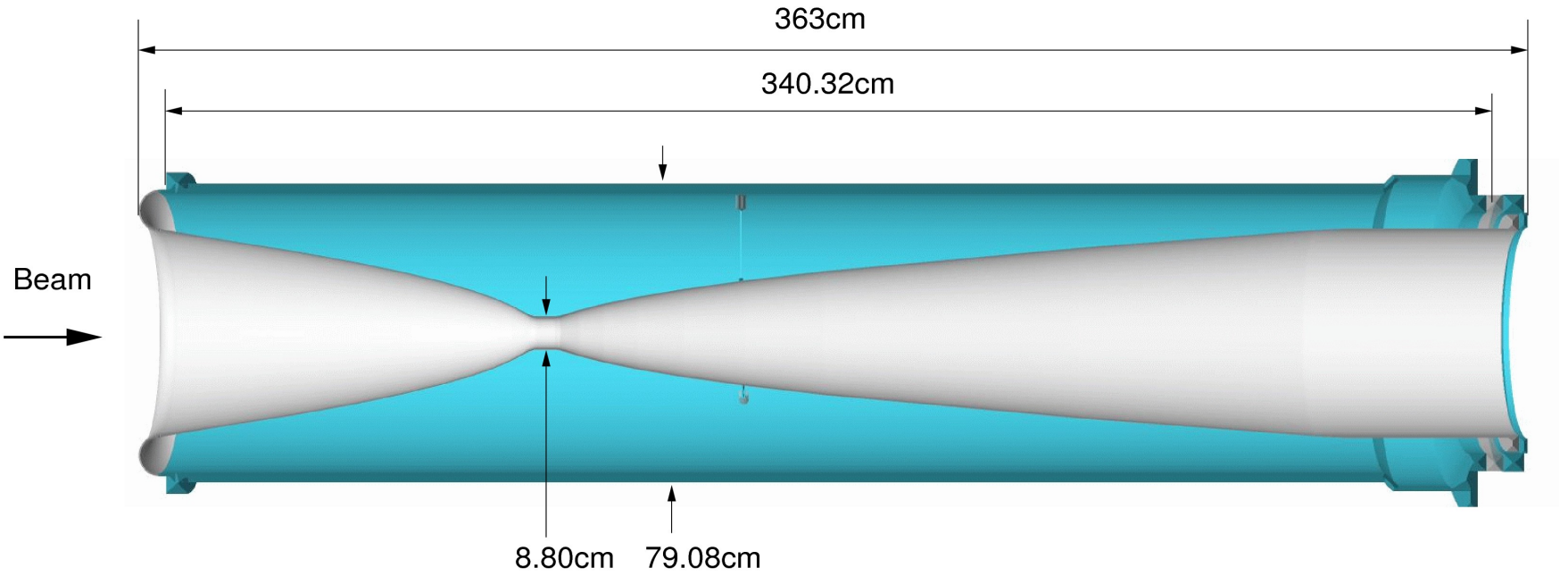


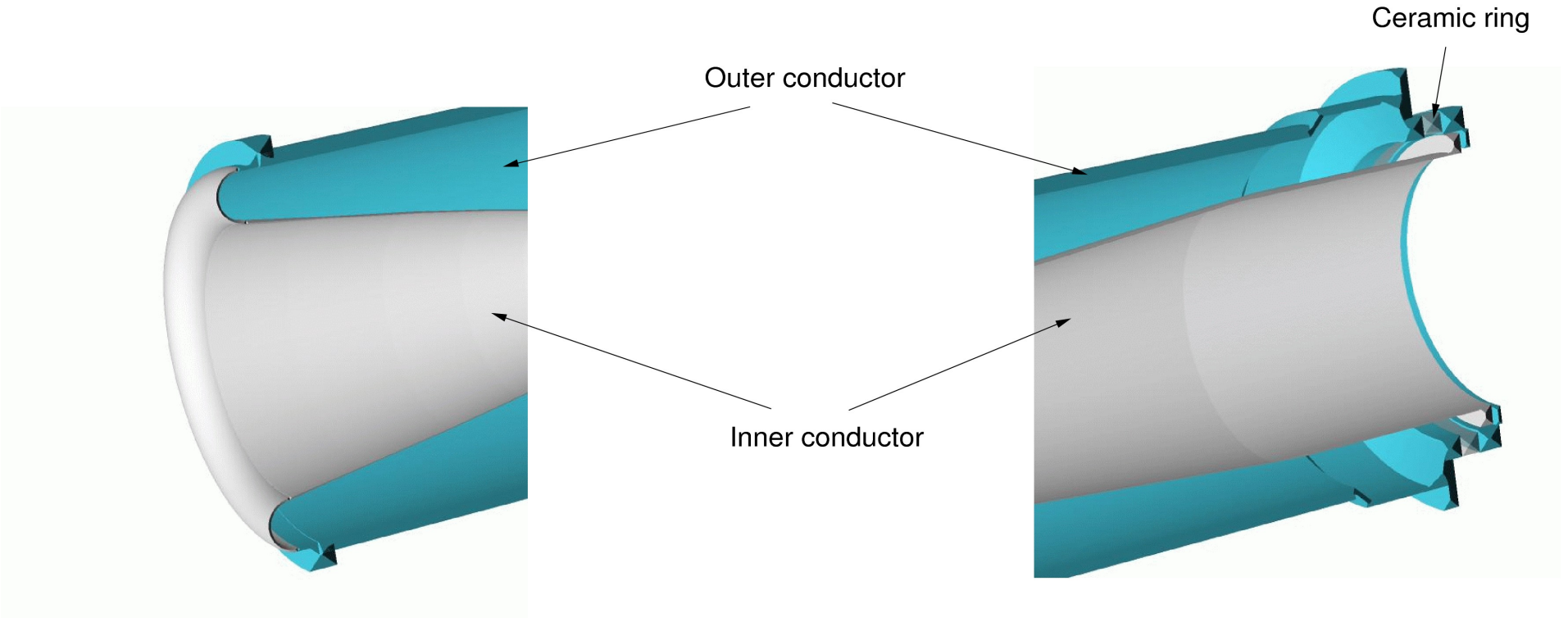
Geometry – horn 1



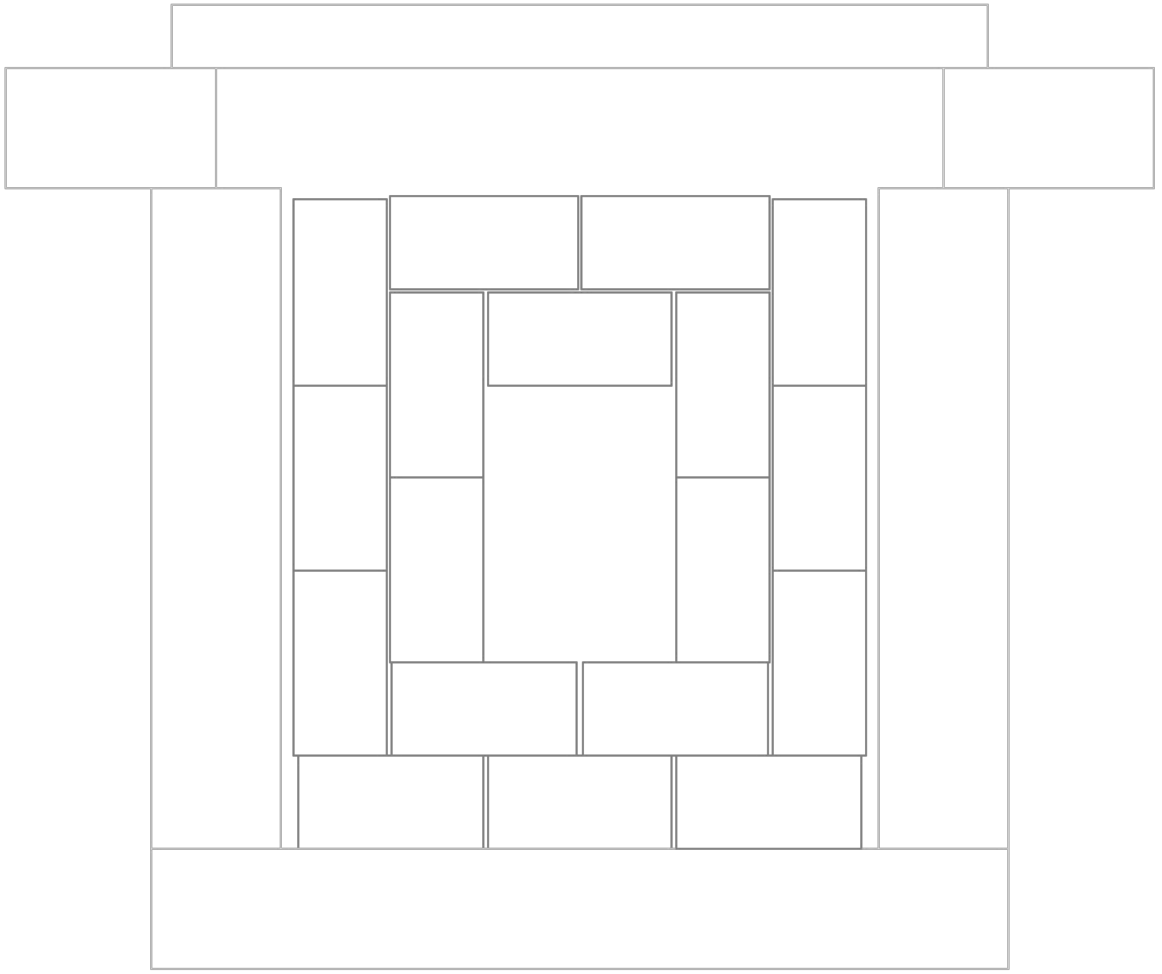


Geometry – horn 2

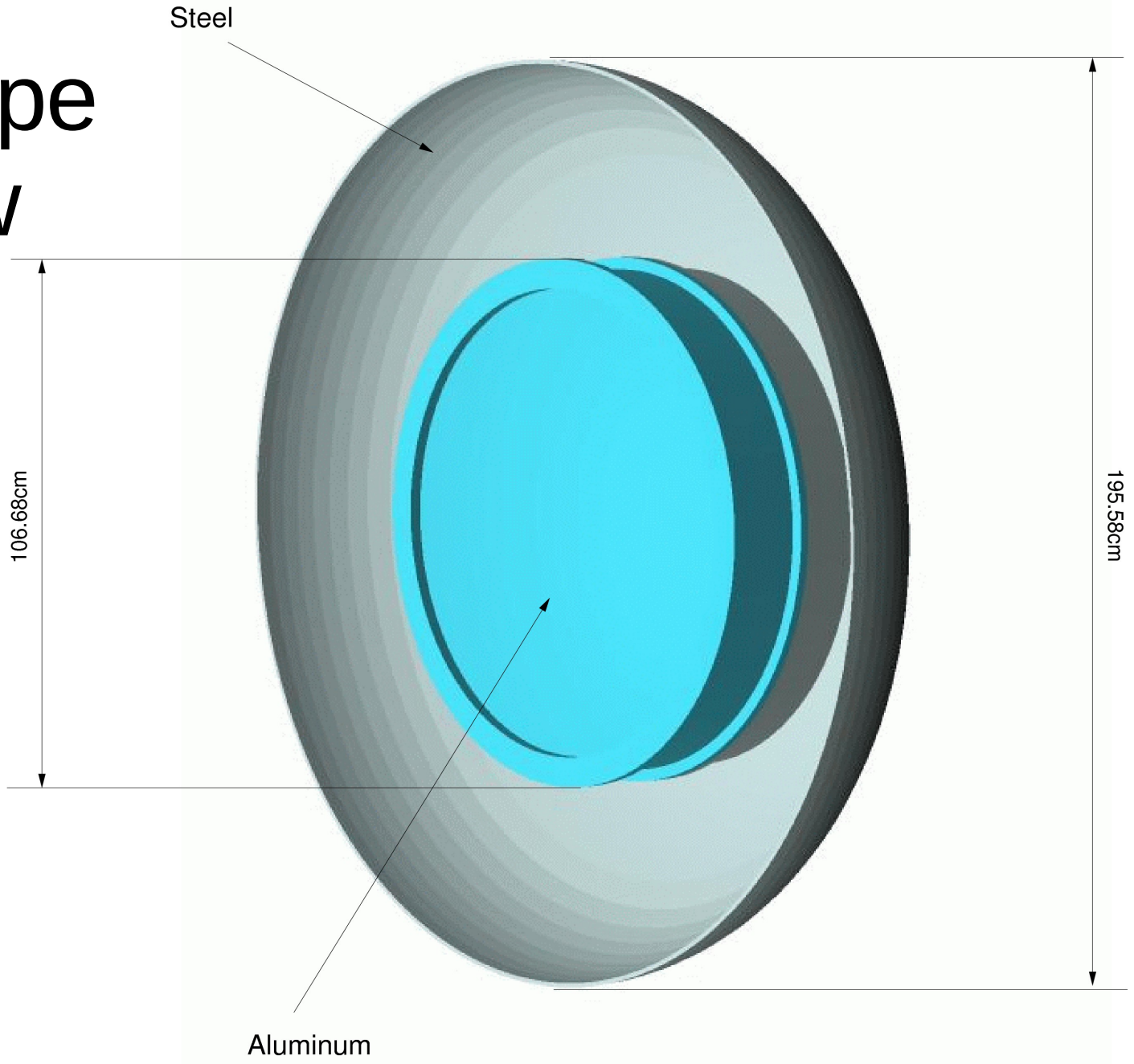




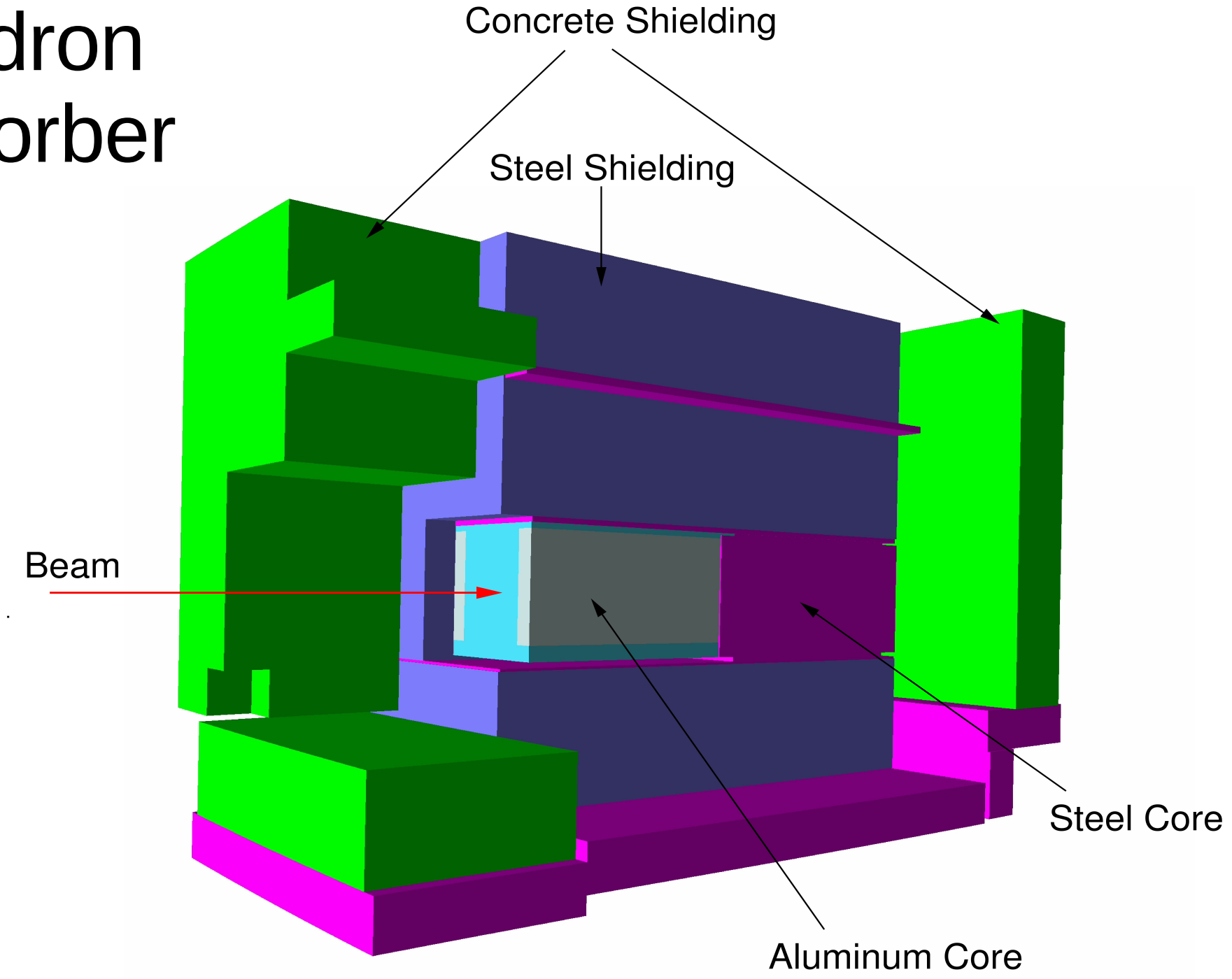
Target hall



Decay pipe window



Hadron Absorber

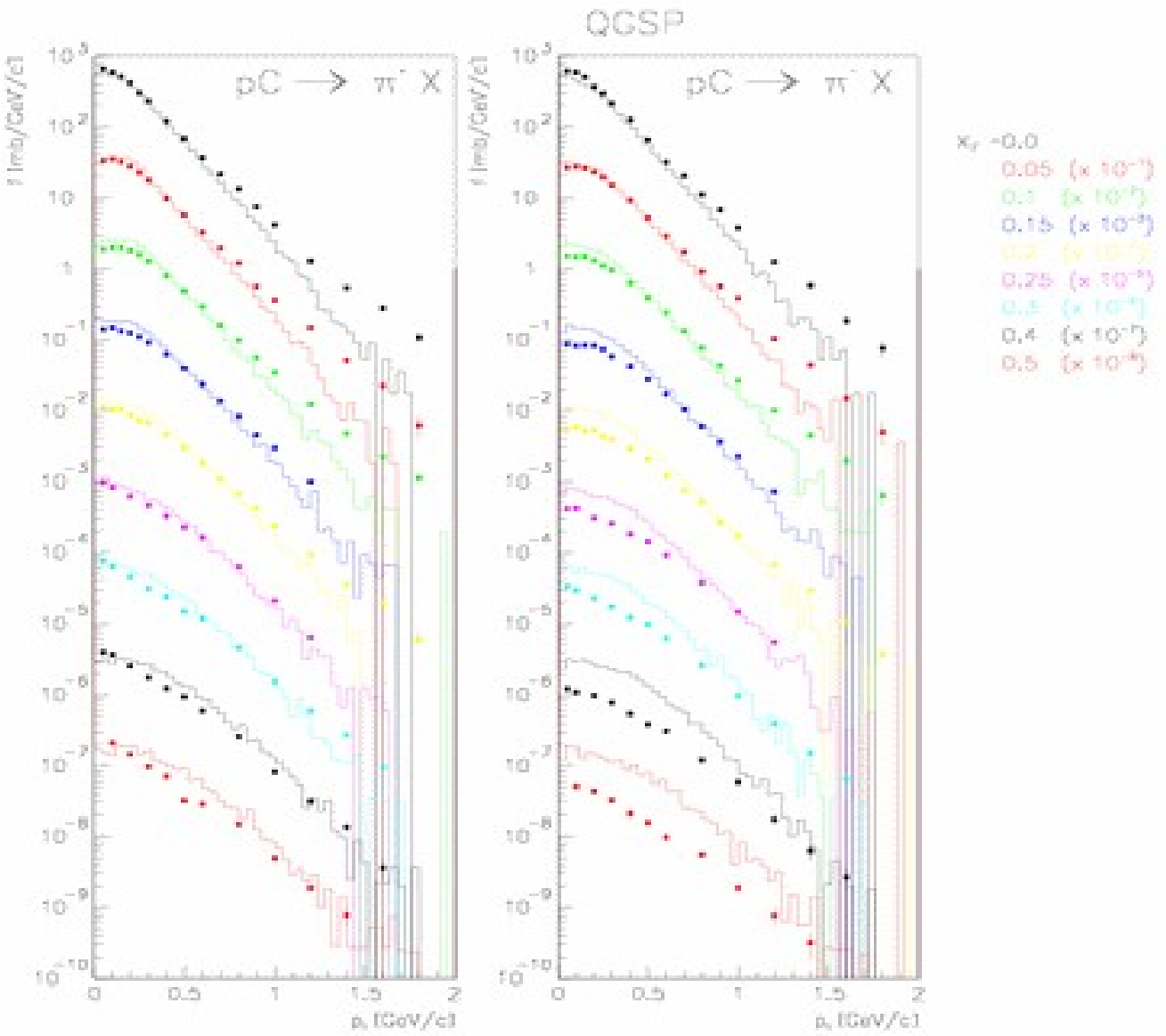


Physics models

- g4numi (without flugg) uses geant4 ready made physics list (QGSP)
- geant4 very flexible
  - Can also make your own physics lists
  - Attach processes to particles
  - choose model(s) used for that process (can use different models depending on energy range)
  - use parameterizations

QGSP

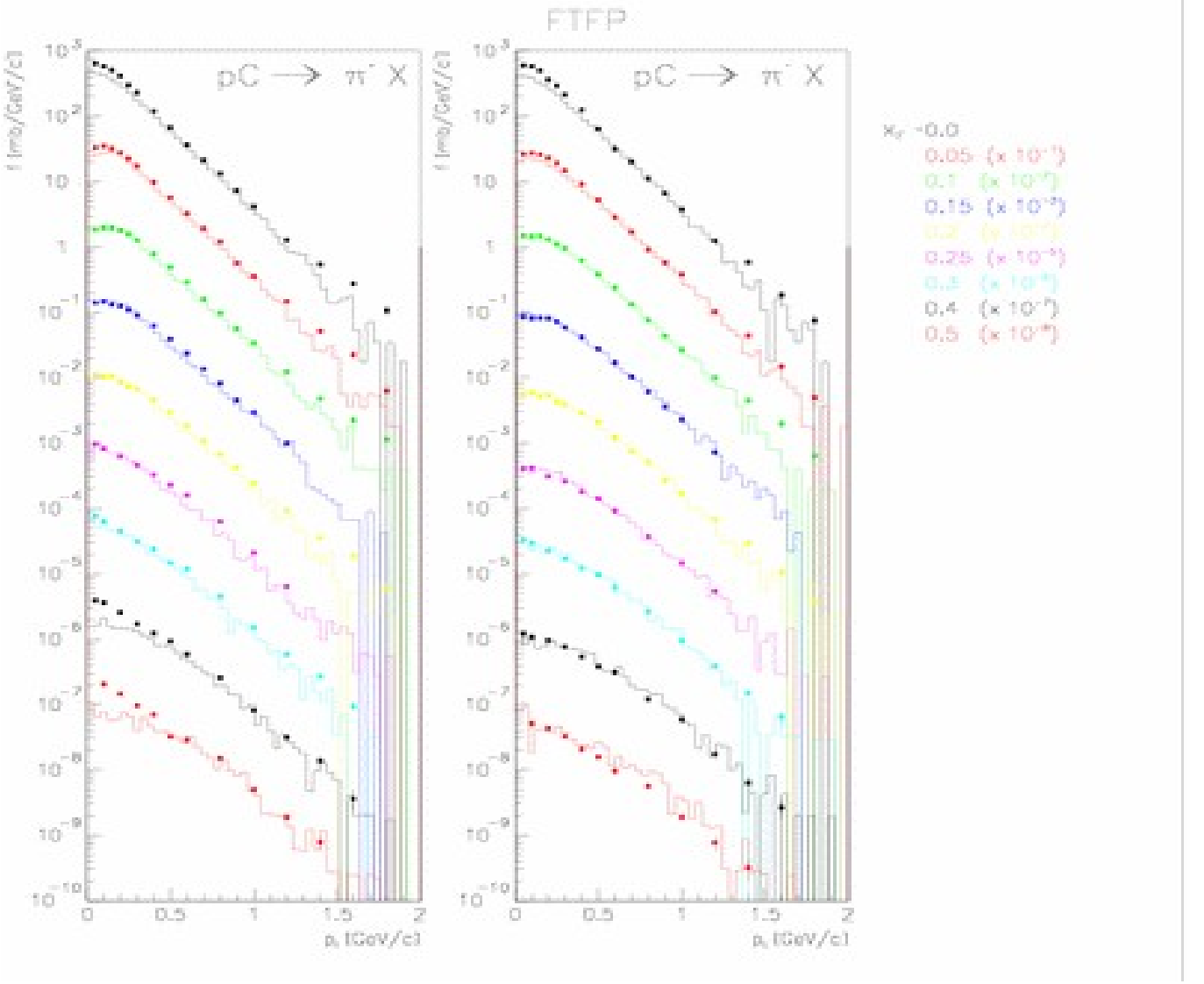
- Geant4 validation with na49 (p+c @158 GeV)
- Study performed by: Gunter Folger (CERN)



http://geant4.fnal.gov/hadronic_validation/validation_plots/thin_target/hadronic/high_energy/na49/na49_data.shtml

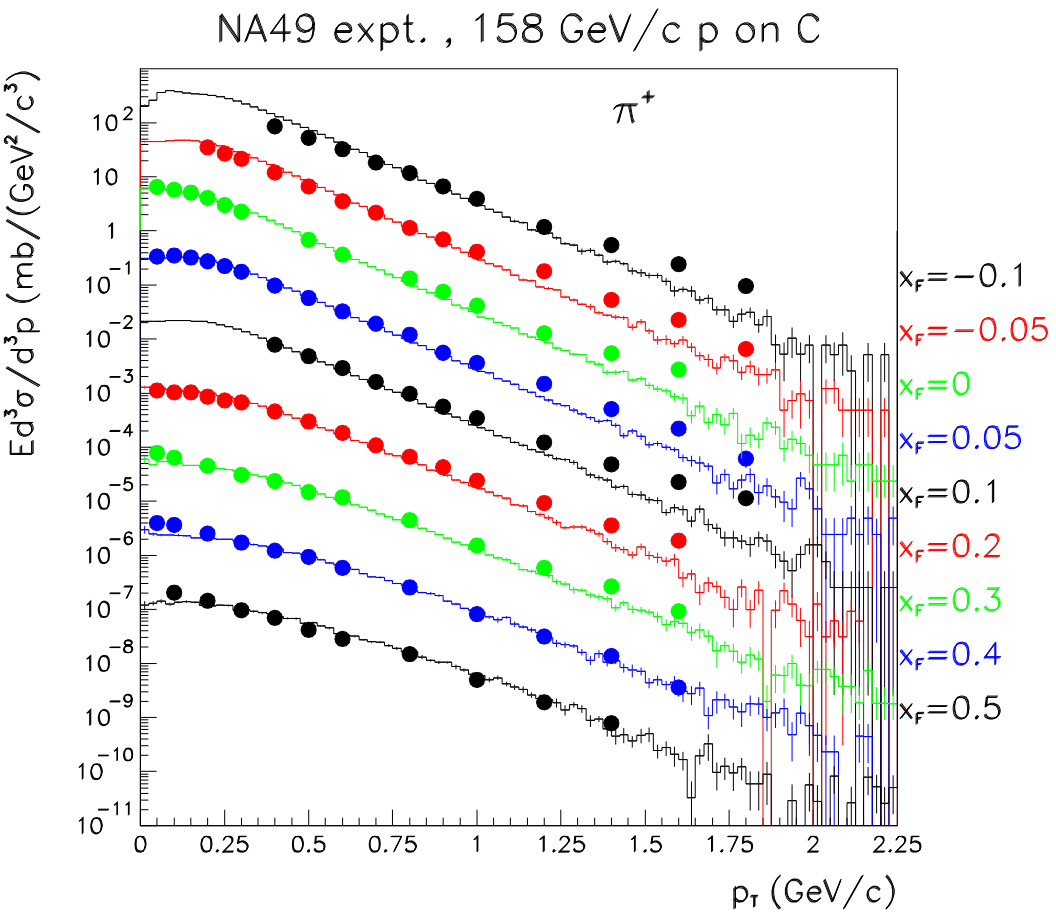
FTFP

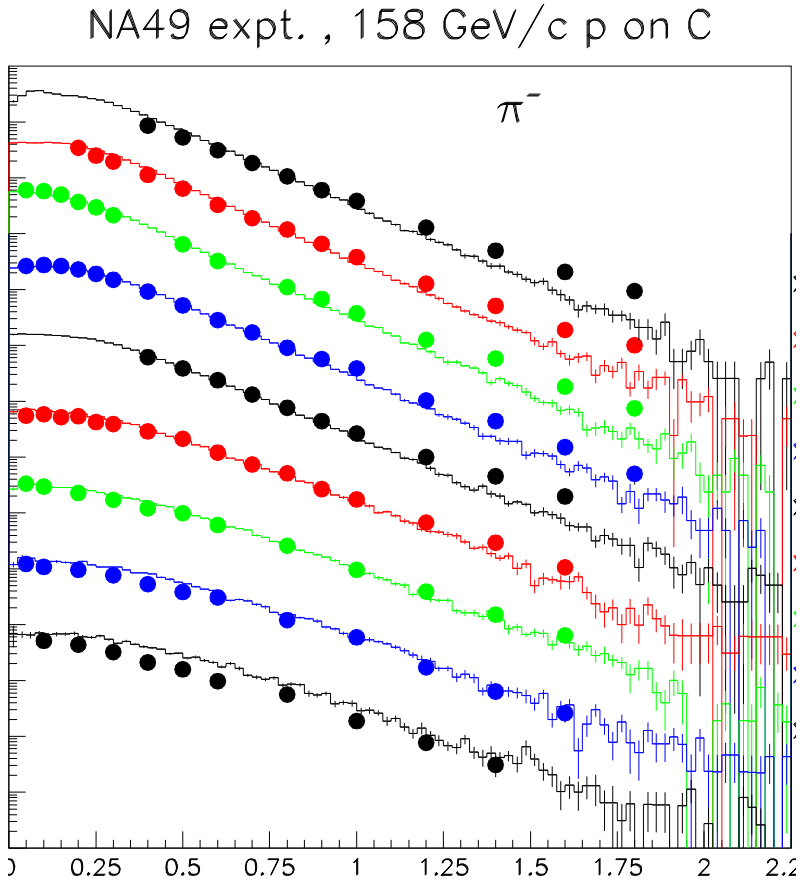
- Geant4 validation with na49 (p+c @158 GeV)
- Study performed by: Gunter Folger (CERN)



http://geant4.fnal.gov/hadronic_validation/validation_plots/thin_target/hadronic/high_energy/na49/na49_data.shtml

Fluka





Plots from a talk by Alfredo Ferrari
(http://info-fluka-discussion.web.cern.ch/info-fluka-discussion/pages/Talks.htm)

G4numi input

- Most of the variables like decay pipe length/ radius, target hall length, horn position are hard coded, etc...
  - Mostly in one place, so can be modified to read from text file
- Some can be changed in run time
  - For example target z position, horn current
  - Exactly how this is done depends if running pure geant4 (inside input macro file) or flugg (use environment variables)

G4numi input (cont'd)

- However, geometry fairly complicated, so making changes not trivial
- Lot of small pieces => have to be careful when moving anything
- Overlapping volumes tend to cause weird problems

Requirements

- Pure geant4:
  - geant4, root
  - g4numi
- With flugg to interface:
  - geant4, fluka, flugg, root
  - g4numi and g4numi_flugg
- On Fermilab machines can use ups to setup geant4 and root; need to install fluka and flugg

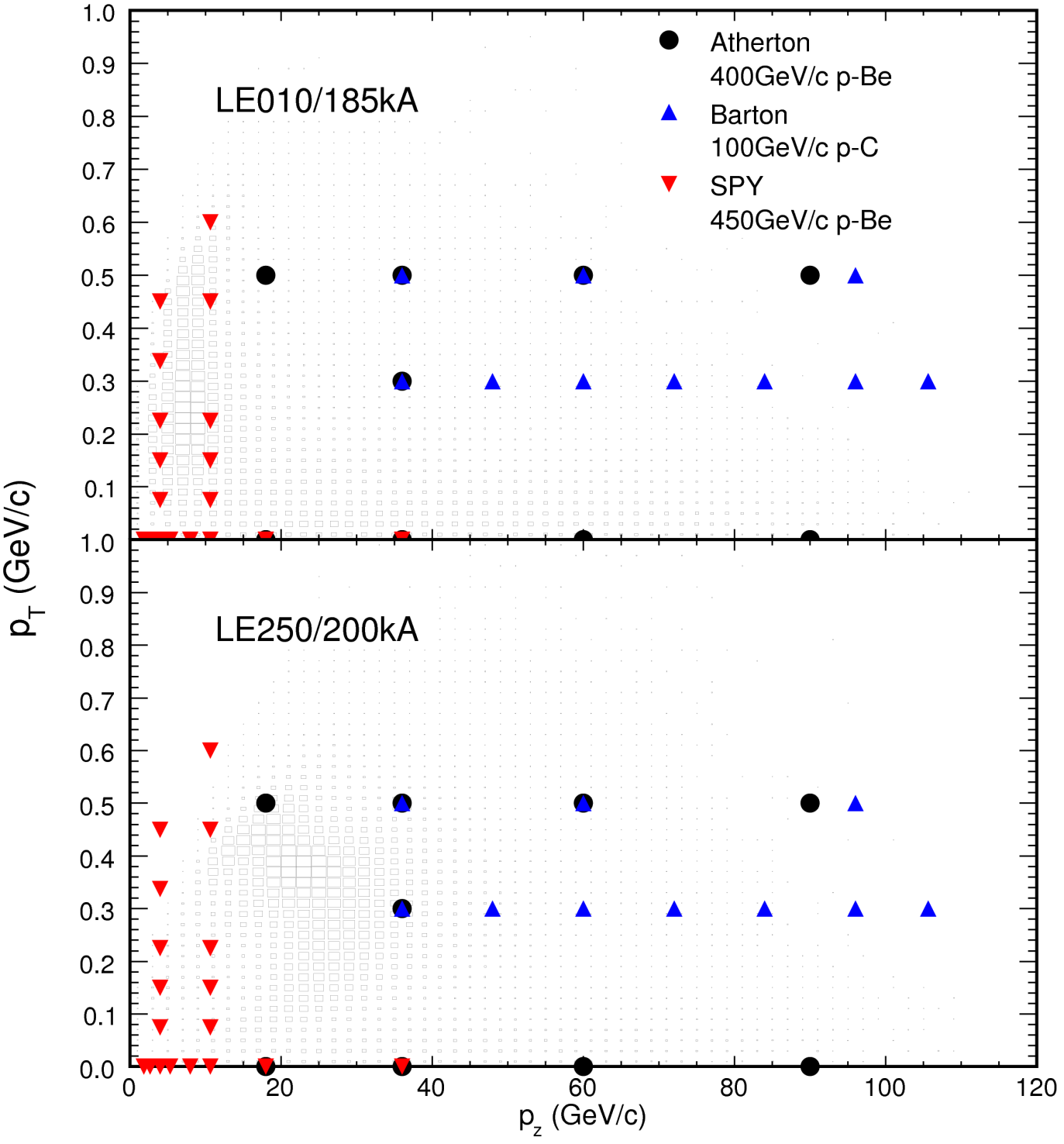
g4numi for lbne

- Could use g4numi as starting point
- Replace parts of geometry
  - Perhaps start with simpler one (easier to make studies)
- Add more input options
- Change output format
  - Output made same as in gnumi to interface easily with minos detector MC
  - Would be better to store the information about all the particles leading to a neutrino

g4numi for lbne

- Geant4 provides many hadronic physics options:
  - Several ready made physics lists
  - Write your own physics list
    - Choose between existing models
    - Add cross sections/parametrization
- Flugg can be used to interface with fluka

Backup


LE010/185kA
LE250/200kA
Atherton
400GeV/c p-Be
Barton
100GeV/c p-C
SPY
450GeV/c p-Be
p_T (GeV/c)
p_z (GeV/c)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
20
40
60
80
100
120